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HUMAN FACTORS EVALUATION OF THE MODULAR LIGHTWEIGHT LOAD-CARRYING EQUIPMENT (MOLLE) SYSTEM

by
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14. ABSTRACT

In March 1994, the Training and Doctrine Command System Manager for the Soldier, the Program Manager Soldier, and the U.S. Marine Corps Systems Command issued a joint call for a front end analysis (FEA) to determine the best design for a load-bearing system for soldiers and marines. The FEA was used in drafting a new user requirements document and initiating the development of a modular load-carrying system which ultimately became known as the Modular Lightweight Load-carrying Equipment (MOLLE). This report presents a summary of the FEA survey and the results from a series of human factors evaluation tests conducted during early MOLLE development. Test methodology and results are presented along with evaluation of the design features of load-bearing equipment important to infantrymen and their missions. This is followed by a discussion of lessons learned in the development of the system.

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Preface

This report describes findings from human factors tests conducted during the early development of the Modular Lightweight Load Carrying Equipment or MOLLE. Programs like MOLLE, to develop a "new and improved" equipment, often demonstrate a predilection for fixing things that are not entirely broken. That's not to say the legacy load-carrying system All-purpose Lightweight Individual Carrying Equipment (ALICE) had no problems. There have been various calls for improvement. However, it would be wrong to assume every feature of ALICE needed to be redesigned simply because parts of the system were not working well. We are tempted, at times, to make radical changes when only minor or selective changes might do. As developers, we often don't appreciate the qualities inherent in the existing items that have evolved with time as we begin our critical look for system improvements. When ALICE itself was first introduced into the Army it came, like most systems, with many new design and material flaws that were subsequently resolved through incremental improvements. We need to first identify and evaluate carefully these evolved qualities as we examine the system for its deficiencies. An earlier program to replace ALICE with a radically different internal frame system based on commercially available backpacks did not succeed, in part, because of the failure to appreciate why certain features, such as the external frame, existed. Fortunately, the effort was not a complete loss since the program did introduce useful design concepts and provided valuable learning experiences for the MOLLE program.

This technical report tells only part of the MOLLE story. There have been many people involved and many man-hours invested in developing MOLLE not cited or reported here. Only the findings of the human factors tests conducted in support of the MOLLE in the early stages are presented. As explained in the report, an early prototype of a modular system was under development before the call for a front-end analysis for a new & improved military load carrying system in 1994. This early prototype was refined based on the front-end analysis and then subjected to the user evaluation tests reported here. The purpose of these tests was to provide early user feedback and data to the design team in support decisions for improvements. What was interesting about this evaluation process was there were times when there appeared to be no connection between the findings of the previous user test and the changes made to the system. This illustrates that, while user feedback is a necessary and valuable part of system development, design engineers frequently must also rely on their own experiences, insights, and intuitions, along with performance data, in judging what improvements are needed or what features should be dropped in the re-design of a system. This was sometimes the case in the development of the MOLLE. That's part of the "lessons learned" reported here. And that is how it should be. Individual end users may not always know what features are best because it often takes performance data combined with technical knowledge about human capabilities or materials and a command perspective of such things as logistics to see opportunities or limitations of various system features. System development certainly needs to be an interdisciplinary team effort.

This report presents human factors "lessons learned". However, we frequently see in hindsight, what we think we should have seen with foresight and then tend to second guess ourselves about not having taken appropriate action. In reality, we most likely cannot make the decisions any sooner than we have since it often takes data and time for reflection to know which are the better choices.

The people who contributed to these human factors evaluations of MOLLE are too numerous to list here but those who should, include the design team: John Kirk (MOLLE Design Team Leader), Richard Landry, MAJ. John Matlock, MAJ. William Mason, Jonathan LaPlume, Chris Palmer, Chuck Green, Dean Rogers, Kyle Hassler and Al Dassionville. The human factors support team include: Edward Hennessy and Martha Fletcher who helped conduct the laboratory and chamber tests at Natick. Among the un-named contributors are all the soldier volunteers who tested and evaluated the prototypes and as well as support personnel who provided their time and labor to the field and laboratory evaluations.

Executive Summary

In March 1994, the TRADOC System Manager for the Soldier (TSM-Soldier), the Program Manager (PM)-Soldier, and the U.S. Marine Corps Systems Command issued a joint call for a front end analysis (FEA) to determine the best design for a load bearing system for soldiers and marines. The FEA was used in drafting a new user requirements document and initiating the development of a modular load-carrying system which ultimately became known as the Modular Lightweight Load-carrying Equipment (MOLLE).

This paper presents a summary of the FEA survey and the results from a series of human factors evaluation tests conducted during early MOLLE development. While test methodology is presented, the main focus is to identify features of load-bearing equipment important to infantrymen and their missions. This is followed by a discussion of lessons learned during development.

Throughout this program short simple, comprehensive, questionnaires were used in combination with relevant field and laboratory activities. Experienced soldiers worked with engineers to design a system that met their requirements. Although the questionnaires varied in minor ways in terms of wording and scales, the results were comparable between tests. In spite of the changes, the questionnaires identified the same strong and weak points of the load-carrying system which ultimately allowed engineers to tweak the design toward needed improvements. This was possible through the use of fixed questions, written comments and focus group discussions. The combined data gave the design team confidence in the results. Furthermore, quantitative scaling of items allowed statistical analysis in support of decision making.

In terms of the test methodology a key lesson was how important it was to select the right user population and test activities. These were more important than the scaling or wording of questionnaires or executing certain experimental designs. Hence, it is important in early development to conduct tests that involve users with job experience, a questionnaire that covers all key issues, and activities that represent the user's operational tasks. It is also valuable to have at least one alternate design to which the user can make comparisons.

In terms of the load-carrying system under development, the most interesting part of MOLLE's evolution was how certain features were identified as problems early, were repeatedly found in subsequent tests in spite of changes but were not dropped until the end. In spite of many product improvements made along the way, there was one feature the users were having fundamental problems with (viz., the quick release mechanism) but which the team would not abandon. This is best understood by the fact that the quick release mechanism was, at that time, one of the early great innovations that appeared to solve a long existing problem. The desire for an instantaneous quick release mechanism existed years before this program began. However, until the first MOLLE prototype appeared, no one had been able to design a mechanism that was both reliable and durable. In addition, the MOLLE belt-release mechanism allowed the elimination of a second belt,

which was identified by users as a key problem with the ALICE. The early excitement and optimism of the new design gave nearly everyone a positive sense of accomplishment and a belief that this feature would ultimately work, once the bugs were worked out. However, after several test-fix-test cycles, the user community decided to waive the quick-release requirement from the operational requirements document.

HUMAN FACTORS EVALUATION OF THE MODULAR LIGHTWEIGHT LOAD-CARRYING EQUIPMENT (MOLLE)

Introduction

In 1988 the US Army adopted a new internal frame load-carrying system. The design was based on commercial backpacks modified for military use with the addition of a special fighting vest and a detachable patrol pack. The original focus was to develop a load-carrying system for use in cold weather. However, in the end, the US Army decided the new internal frame pack would be the replacement for the external framed All-purpose Lightweight Individual Carrying Equipment or ALICE system. Production and distribution started in 1990 but by 1993 it was evident that the new internal frame pack was unacceptable to a large number of combat personnel.

Although a key problem with the internal frame was durability due to poor manufacturing, the system was also judged to have some basic design flaws. Based on a survey of users by the US Army Training and Doctrine Command (TRADOC), soldiers claimed the pack was too hot against the back in warm climates, and was unstable and uncomfortable when heavily loaded. While many of the features of the system were liked (e.g., the patrol pack, and capacity of the main pack), it was judged not to meet the overall requirements of the Army. In spite of this rejection, most units surveyed (6 of 9), still favored having both load-carrying systems: the ALICE for warm and temperate climates, and the internal frame system for cold weather operations.

In March 1994, the TRADOC System Manager for the Soldier (TSM-Soldier), the Program Manager (PM)-Soldier, and the U.S. Marine Corps Systems Command issued a joint call for a front-end analysis (FEA) to determine the best design for a load-bearing system for soldiers and marines. The FEA was employed to draft a new user requirements document and officially initiate the development of a modular load-carrying system which ultimately became known as the Modular Lightweight Load-carrying Equipment (MOLLE).

This report presents a summary of the FEA survey and the results from a series of human factors evaluation tests conducted during early MOLLE development. While test methodology is presented, the main focus is to address and identify important features of load-bearing equipment critical to infantrymen and lessons learned during testing.

Approach

For the FEA, a user questionnaire and a group interview form were developed from statements collected from soldiers and marines as well as from information obtained from the 1988 technology demonstration on Lightening the Soldier's Load (ref. 2). Questionnaire items asked about the type of load bearing equipment (LBE) in current use, types of problems encountered and solicited recommendations for improving LBEs. Pilot tests were run to refine wording of the questions and statements. Questionnaire items were pre-structured statements based on all the issues identified and were either numerically scaled 0 to 4 (with verbal labels None to A Lot), verbally scaled (Strongly Agree to Strongly Disagree) or were simply check-off lists of key issues. At the end of the questionnaire, respondents were asked to write down any suggestions they had for improvements. The results were then used as a framework for the user focus-groups referred to here as "muddy boot" teams.

Over a period of seven months, questionnaires were distributed to over 2,000 soldiers and marines by U.S. Army Natick Operational Forces Group during its routine surveys of users of Natick developed food, clothing, shelters, and individual equipment items. Five US Army posts (Forts Bragg, Campbell, Drum, Hood and Lewis) and two US Marine Corps sites (Camps Mabry and Lejeune) were visited. All those surveyed had experience with the ALICE, and 40 percent also had experience with the recently introduced internal frame system. Highlights of the results are presented below. In addition, results from a series of eight user tests (unpublished) on MOLLE are presented. All tests involved experienced soldiers who evaluated candidate systems during simulated tactical movements in the field and laboratory.

For the user tests, a series of short but comprehensive human factors (HF) questionnaires was developed and modified slightly for each test condition. In general, the items in the questionnaire (see Appendix A) covered the issues addressed in the FEA as well as the resulting Operational Requirements Document (ref. 3). Each item was a phrase or term relating to a system feature or performance objective. Each phrase was followed by a numeric rating scale. Various scales were used and wording changes were introduced from test to test, but results show the questionnaires elicited fairly consistent responses across tests. Changes in the numeric rating scale and wording were judged to have little, if any, impact on results. In other words, the same design weaknesses were identified consistently from test to test with some variation attributed to improvements in MOLLE made along the way. Quantitative analysis of the scaled questionnaire was reinforced by written comments by the soldiers at the end of each questionnaire and by statements made during group discussions.

All tests reported here involved experienced soldiers performing their routine activities such as road marches, individual combat movements and/or squad patrol or ambush training activities. During these events the soldiers were required to don and doff loads repeatedly. Most test activities took several hours or days and were followed by sessions for completing questionnaires and team after-action reports. The tests were conducted at various locations and under a variety of conditions. One test, for example, was conducted in tropical heat with soldiers stationed in Panama, while another involved activities in the Natick large arctic cold chamber with experienced cold weather soldiers from Ft. Richardson, Alaska.

During some of the early tests, MOLLE was evaluated along side other candidate modular systems while in the later tests MOLLE was either tested alone or with ALICE. In all tests volunteers were asked to rate MOLLE against their current LBE, viz., the ALICE. Upon completing the individual questionnaire, the team was brought together for group discussion. In most tests, the field actions and group discussions were video recorded for later review and analysis. The FEA and these early developmental tests are briefly described below along with brief summaries of results, followed by discussion of lessons learned.

Results

Front End Analysis 1995

The FEA survey resulted in 1,844 fully completed questionnaires by soldiers and marines from eight military specialties. Fifty-six percent of the respondents were Combat Infantrymen, 14% Combat Engineers, 8% Medics and the remainder were Communications, Chemical, Mechanic, and other support specialists. The respondents were given 32 statements about their current load-bearing system and asked to indicate whether they agreed or disagreed, slightly or strongly, with the statement. These statements reflected issues related largely to deficiencies of

their legacy system, the ALICE (see Table 1) as well as to the recently introduced internal frame system. The respondents were also asked to provide suggestions for future developments of a military load-carrying system.

Table 1. ALICE Design Deficiencies

- Does Not Accommodate Loads of RTO, Grenadier, AMG, Medic Or Other Squad Positions
- Cannot Be Easily Tailored For Changing Missions
- The Two Belt System Is Problematic:
o LBE Belt Not Used To Distribute Load
o Load Rests Mainly On Shoulders
o Design Leads To Need For More Padding
- No Quick Drop Mechanism For Main Rucksack
- Cannot Fire Rifle While Prone With Load

In addition to the survey, two "muddy boot" panels (Ns = 5 & 7) were conducted at Fort Benning, Georgia in September 1994, where each panel discussed, independently, the same set of questions as presented in the questionnaire. The two panels then reviewed their judgments together and were asked to arrive at a consensus about Army requirements for a new load-carrying system. Some of the key questions developed for the FEA as part of the muddy boot exercise are shown in Table 2.

Table 2. The FEA Load-Bearing Equipment Issues

- What Load Classification System Should Be Used?
- How Many Unique LBE Systems Needed?
- What Type of Frame is Best for Army?
- Should System Be Modular or Integrated?
- What is the Minimal Configuration?
- How Many Sizes? vs. How Much Adustability?
- What Should Be the Capacity of Packs & Pouches?
- How Important Top Loading vs. Bottom & Side Loading?
- What Strap & Belt Systems are Best?
- How Quick is "Quick-Release"?
- How Essential is Firing Weapon Prone with Load?
- How Durable Should System Be?
- How Important is Cleaning & Repair?
- What are the Major Compatibility Problems?
- How Important Padding, Cinching, Water Proofing & Camouflage?

Key findings of the FEA are shown in Table 3. These include a call for a slight increase in rucksack capacity over the ALICE Large and an improvement in the capability to configure loads for different squad members and missions. While it was recognized by the military participants that greater capacity would mean a greater potential to overload the soldier, the need to hold specialized items and the ability to quickly arrange and extract needed items from the pack were judged more important. In turn, since heavy loads are nearly impossible to avoid during most real world missions, durability of the system and the added support provided by an external frame were also identified as important requirements.

The high rating on the Ability-To-Reconfigure requirement and the need to tailor loads strongly suggested the system should be modular. The emphasis on modularity was supported by the results of the Lightening the Soldier's Load Technology Demonstration of 1988. That demo concluded that modular equipment allows fighting units to reduce loads through mission tailoring in theater. The dilemma was that most removable components tend to lack the stability of fixed, sewn-on components of the LBE system. Thus, if the modularity concept was to work, a pouch attachment mechanism which would provide good stability was needed.

Table 3. Results of FEA Load Bearing Equipment Survey

- Capacity of System: Slightly Greater Than ALICE
- Make Modular: Tailor for Squad Positions & Missions
- Durability: Must Pass 55kg Drop Test
- Compatibility: Body Armor, Weapons, Other CIE
- Compatibility: Airborne Ops
- Make Water Repellent, Provide Drainage in Pouches
- Frame Support: Heat Flow & Heavy Load Stability
- Load Distribution/Stability: Comfort, Low Energy Cost
- Make Packs & Frame Lightweight
- Quick Release of Contingency Load (Main Ruck)

Focus was also given to the need for quick release of the main pack. While quick removal of the main rucksack has been a long desired feature, extra emphasis was given to this during the FEA. The FEA called for the development of a quick (instantaneous) release mechanism. Discussions on the ease of donning and doffing of the rucksack lead to concerns about multiple belts and harnesses and the desire to simplify the system. This was reinforced by the expressed desire to make the load-carrying system more compatible with other equipment by eliminating competing belts and straps. For increased comfort, users asked for more padding, particularly on the shoulder straps. This was because soldiers tended not to use their hip belts in order to quickly drop the main pack when fired upon.

There was a need for a functional hip belt to help distribute the load, but also allow the pack to be dropped quickly in emergencies. Thus, the FEA recommended the concept of a padded hip belt and other features for distributing or adjusting the load during prolonged road marches, plus a quick release feature.

The FEA also presented a list of other issues, features, and performance requirements, such as camouflage, noise attenuation, water resistance, shouldering of the weapon, ability to clean, compatibility with other equipment, and so on. The FEA draft Requirements Document included nearly all of these with varying degrees of emphasis. From this draft ORD, TRADOC developed the official ORD for the development of a new modular load-carrying system (ref. 3).

MOLLE 1997

In part, the MOLLE grew out of in-house research and prototyping of load systems by a team of engineers at Natick. While much work was done prior to the FEA work the FEA had a significant impact on the subsequent design. At the time of the ORD an in-house design became the prototype load-carrying system for the U.S. Marine Corps and soon incorporated many, if not all, of the required and desired features called for in the Army's FEA and ORD. Chief among these

were a modular pouch system and rucksack, a durable external frame with a reliable and durable quick-release mechanism, a padded hip belt, and, as a result of the design the elimination of the need of a second belt for the load-bearing harness. The main pack and added pouches of this early MOLLE had a capacity slightly greater than ALICE's large rucksack and included special sized pouches to accommodate items for different users and missions. In addition, the system included an attachable patrol pack, as well as a butt pack and fighting vest that allowed re-configuration of ammunition and other pouches. The real key to making this early system a viable alternative to ALICE was the innovative design of the attachment mechanism for modular pouches, gives each pouch a sewn-on quality, yet allows easy removal or re-attachment to new locations on the load-carrying system. The other promising feature was the highly durable and reliable quick release mechanism for rapid dropping of the main pack. Prior to this date no system worked well enough to be seriously considered to replace the ALICE attachments (see description of MOLLE in Appendix B).

Fort Campbell, Kentucky 1997

The first Army user evaluations of the MOLLE prototype and another modular candidate was conducted at Fort Campbell in October 1997. Twelve US Army 101st infantry soldiers ran through an obstacle course wearing the full LBE system and a simulated load or just the fighting vest of each candidate system. Performance activities included climbing under, over and through obstacles, low crawling, stepping or vaulting over barriers, balanced walking and a 5 kilometer march with a 23 kg weighted load. Between obstacles the soldiers had to doff and re-don the main rucksack several times. Following these activities the volunteers completed the Natick HF questionnaire and participated in group discussions to compare MOLLE with ALICE and the competing system. Ratings of key features are shown in Table 4. The MOLLE was rated higher than the competitive system and only slightly higher than the ALICE. MOLLE scored highest on Modularity, Quick-Release, Ability to Open Up, Quality of Closures, Holding Capacity, Stability of Pouches, Comfort with Loads and Durability. It scored low on Ability to Fire Weapon Prone, Expected Utility in Deserts, Quietness, Ability to Re-Attach Quickly, Heat Ventilation, and Ability to Climb Over Things While Wearing. Comments from soldiers indicate problems with the re-attachment of the quick release frame mechanism, discomfort in the small of the back, and shifting of the main ruck when fully loaded. Soldiers with a shorter stature seem to have the most problems with the frame attachment mechanism. Based on these results the MOLLE was modified to make it easier to don by changing the probe and socket design and shortening the frame.

Table 4. Fort Campbell, KY
Mean Ratings (n=12)

Feature / Quality	Rating
Highest Ratings	**(0 - 5)**
Re-configurable	4.9
Quick-Release	4.7
Pouches	4.7
Take-off Quickly	4.6
Open Up	4.5
Better Than ALICE	4.4
Holds Mission Items	4.4
Closures	4.4
Pouch Stability	4.2
Adjustability	4.1
Comfort w. Load	3.9
Durability	3.8
Lowest Ratings	
Fire Weapon Prone	2.3
Good for Desert	2.7
Quiet	3.0
Reattach Quickly	3.0
Ventilate Heat	3.2
Climb Over Things	3.2

Fort Benning, Georgia 1997

The second evaluation of MOLLE was conducted with another group of US Army Rangers (n=13) at Fort Benning in December 1997. Prior to conducting mock patrols and ambushes in the field, the soldiers were fitted to the MOLLE and given instruction on its use. They practiced donning and doffing the ruck many times before going out to the field. They then spent much of the day in the field conducting various tactical movements in small teams. At night they went through maneuvers to evaluate using the system in the dark. Following these activities they completed the Natick HF questionnaire and participated in focus-group discussions. The results again indicated the soldiers preferred MOLLE over the competitive system and only slightly over ALICE. They rated the modularity and pouch design very high. The loaded ruck was judged as highly stable and the frame durable. They liked the H-harness and the ability to shift the load while moving by adjusting the cinching straps. Again, their greatest concern was the frame locking mechanism, time to don the rucksack, top-heaviness of a full load and the noise made by the frame. There also were safety concerns (e.g., fingers getting caught in the locking mechanism). The MOLLE frame continued to undergo design changes to increase durability and to improve the operation of the quick-release attachment mechanism.

Table 5. Fort Benning, GA
Mean Ratings (n=13)

Feature / Quality	**Rating**
Highest Ratings	**(0 - 5)**
Reconfigurable	4.7
Hold Mission Items	4.6
Repairable	4.5
Durable	4.4
Quick-Release	4.4
Comfort while wearing	4.4
Pouch Stability	4.4
Load Stable	4.4
Comfort while Walking	4.3
Better than ALICE	4.3
Take-off Quickly	4.2
Adjustable	4.2
Lowest Ratings	
Fire Weapon Prone	1.6
Quiet	2.4
Tight	2.4
Crawl Under Things	2.4
Low Crawl	2.7
Reattach Quickly	3.3

Fort Kobbe, Panama 1998

The MOLLE was then evaluated by a US Army test agency at Fort Kobbe, Panama in June of 1998. Here 49 soldiers used the MOLLE over several weeks, after which they were given a series of questionnaires including Natick's human factors questionnaire. The scale of the Natick questionnaire was changed from a 0 to 5 scale to a 3+ to -3 scale to accommodate the tester in Panama. The associated rating adjectives were changed to match the new scale. The change in scale does not appear to have changed the relative ratings across features. That is, the data showing the features that were rated highest and lowest with the old scale were the same features identified with the new scale. Again, the highest ratings were obtained for the design of pouches, stability of pouches, clean-ability, repair-ability, capacity to hold mission items, reconfigure-ability, range of motion and feel while walking (Table 6). The lowest ratings were for operation of frame-locking mechanism, re-donning times, problems low crawling, firing weapon prone, and crawling over and under things. Quietness got a relatively high rating of 60% favorable. However, nearly all the negative ratings continued to be related to the quick-release attachment system in spite of improvements made, the change in user population, and change in test administrators. It is important to note that modifications to improve the MOLLE were being made almost continuously during these early test trials which tended to pose a problem for testers who are used to doing tests on end items. These testers felt as if they were trying to hit a moving target. In spite of the many changes from test to test, the results in each case appear to be fairly consistent across these early

tests.

Table 6. Ft. Kobbe, Panama
Percent Positive (n=23)

Feature / Quality	Rating
Highest Ratings	**(%)**
Pouch Quality	95
Pouch Stability	86
Clean & Repair	84
Hold Mission Items	78
Closures Quality	78
System Fit	76
Reconfigurable	74
Weight of System	74
Ability to Move Arms	74
Comfort Walking	74
Storing	74
Better than ALICE	74
Lowest Ratings	
Frame-Lock Mechanism	26
Reattach Quickly	26
Low Crawl	33
Fire Weapon Prone	35
Crawl Under Things	35
Crawl Over Things	43

Glove Compatibility Test, Natick Soldier Center 1998

Based on anecdotal reports from U.S. Marine Corps testing, MOLLE was judged not to be operable with standard issue army gloves. Therefore, a series of repeated timed tests were conducted at Natick comparing the MOLLE and ALICE with volunteer soldiers (n=6) wearing gloves (July 1998). Tasks included removal of the SINCGARS radio from main ruck, unbuckling LBE, quick drop of ruck, reattachment of ruck, removal and reattachment of canteen, and the insertion and removal of magazine cartridge with and without gloves. The results show the volunteers could operate the MOLLE as well as they could the ALICE. In fact, for many activities (SINCGARS removal, quick release, removal canteen, insert magazine), volunteers performed better ($p< 0.01$) with MOLLE than ALICE due to improvements in snaps and fasteners. The only aspect of MOLLE that was worse than ALICE was the soldiers' donning of the rucksack. It took an average of 29.0 seconds to don MOLLE, while it took an average of 26.2 seconds to don ALICE. However, this was true both with and without gloves. Once again, the frame quick-release attachment was found to be a problem for the user in spite of a number of improvements. While some soldiers could re-don the pack reliably, there were many others who were unable to do so with any consistency .

Although there was insufficient evidence at this point, observations suggested that certain body dimensions of individual soldiers might have played a role in the ease or difficulty of donning the MOLLE. It may have been that individuals with certain back and arm lengths, as well as certain curvatures of the back, were having more difficulty

Natick Cold Chamber 1998

In September 1998 Natick conducted a week-long test of the MOLLE along with the new Interceptor body armor in the arctic cold chamber using experienced cold weather soldiers from Fort Richardson, Alaska. The volunteers brought their own cold weather gear and ALICE systems for comparison. Following several days timed donning and doffing of loads, conducting tactical movements and marching in the cold (-23.3θ C, wind-speed 4.1 kph) with 23 kg loads the soldiers completed the Natick HF questionnaire (scale –3 to +3), modified for cold weather operations. The team was also put through an after action review. The results are fairly similar to previous tests. These soldiers rated Reconfigurable very high. They also liked the capacity it had to hold bulky cold weather gear. They liked the stability of pouches and the overall comfort. As in previous tests, these soldiers found the re-donning of the MOLLE pack difficult and gave a low rating to the detachable frame concept. They had trouble aiming their weapon while prone and shouldering the weapon with MOLLE and the body armor.

Table 7. Natick Cold Test
Percent Positive (n=12)

Feature / Quality	Rating
Highest Ratings	**(%)**
Reconfigurable	100
Holds Mission Items	74
Stability of Pouches	74
Weight of System	74
Quality of Pouches	74
System Fit	74
Feel on Shoulders	74
Comfort	74
Feel on Back	66
Comfort Walking	66
Balance	66
System Stability	66
Lowest Ratings	
Fire Weapon Prone	8
Use CW Gloves	8
Low Crawl	8
Reattach Quickly	16
Shoulder Weapon	16
Open to Vent	16

Fort Polk, Louisiana 1999

A variation of the MOLLE fighting vest (the "RACK") with shorter frame and "attached" or fixed belt was tested at Fort Polk with US Army Rangers during a field exercise in April 1999. The attached frame meant there was no quick release, much like the ALICE. Forty-nine out of seventy soldiers completed the Natick HF questionnaires (scale: -3 to +3) which also included questions on amount of time worn and usefulness of specific features. To accommodate various

equipment items, special modular features were added to the MOLLE including a Leg Bag, PRC-126 Radio Pouch, and Saber Radio Pouch. The results mirror many of the earlier tests, with MOLLE receiving high scores on Ability to Reconfigure, Design of Pockets and Pouches, Durability, Closures, Stability of Pouches, and Comfort while Walking. Low scores were obtained on Ability to Fire Weapon in Prone Position, and Put-on and Take-off Quickly. In spite of the shortened frame, there were still complaints of the frame being too long. More accommodations were needed for soldiers with shorter body dimensions. *While MOLLE continued to be rated low for ability to fire weapon in prone position, many soldiers admitted they would not expect to fire prone with a fully loaded rucksack* [emphasis added]. Furthermore, no one knew of a backpack that would allow soldiers to aim and fire their rifles prone. Thus, it appears this requirement was unrealistic from the start.

Natick Soldier Center 1999

The last and most recent test of MOLLE using the Natick HF questionnaire was conducted in October 1999 and involved the evaluation of alternative frame attachments. These were: 1) the standard MOLLE single-probe quick-release; 2) a modified single- probe quick-release; 3) a double probe quick-release and 4) a fixed belt-to-frame system. Six US Army Rangers went through simulated squad movements at Natick's "Fight-ability Course" and a 2-mile march. The volunteers carried 23kg and practiced donning and doffing the load repeatedly. In addition to being timed on the various designs, they completed the HF questionnaire and rated each system. For this test the scale was changed from a range of -3 to +3 to a wider range of -5 to +5. This allowed the user a greater range of responses and provided greater sensitivity during analysis.

The results show that the fixed belt version was rated extremely high relative to all other quick release designs. In this test, the volunteers evaluated all the quick release candidates before they were given the fixed belt version of MOLLE. The ratings for the two point quick release frame were higher than the one point for Balance and Stability. The two single point versions were rated higher on Comfort. Then, after the soldiers used the fixed belt version, the MOLLE was rated significantly higher on almost everything (see Table 8). The results show the soldiers overwhelmingly preferred the fixed belt over any of the quick releases. Every volunteer was ready to trade his ALICE for the fixed belt version of MOLLE on the spot.

In January 2000, the TRADOC Systems Manager – Soldier stated that it would no longer require the quick release to be part of the MOLLE. As a result, the fixed belt version became the Army test candidate. The Marine Corps also agreed to test the fixed belt version, a product-improvement program, to its already fielded single-point quick release MOLLE that was type classified in April 1999.

Table 8.
Rangers' Evaluation of Probe-Attachments
Mean Rating (n=6)

Feature	MOLLE	1-PROBE	2-PROBE	ATTACHED
Quietness	-2.83	-0.67	-2.00	4.00
ProbeDesign	-2.83	-1.83	-1.50	
Donn Quickly	-1.83	-0.50	-1.50	4.50
Feel Back	0.00	0.67	0.17	3.67
Belt Design	-1.33	1.17	-0.67	4.67
Feel Hips	-1.00	1.83	0.00	3.33
Bend Body	-0.83	1.33	-0.17	3.83
Bend Arms	0.50	1.17	0.83	3.17
Stability	0.00	0.33	1.83	4.67
Adjustability	-0.33	0.33	0.83	3.50
RuckFit	0.67	-0.17	1.17	4.33
Reach Pockets	-0.20	-0.20	0.00	2.40
Balance	0.83	1.17	2.17	4.67
Feel Shoulder	2.17	1.67	2.50	3.67
Doff Quickly	0.17	1.67	1.00	4.00
Comfort	1.00	1.67	0.83	4.33
VestFit	0.67	0.50	-0.17	3.40
Ability Run	1.17	0.80	0.17	4.00
Ability Walk	2.33	1.83	1.67	3.83

Scale: -5 to +5

Discussion and Conclusions

In the early phases of the program to develop a new load-carrying system for soldiers and marines, a comprehensive front-end analysis was conducted which surveyed key users and identified a critical set of issues and requirements. From the FEA a detailed users' operational requirements document (ORD) was developed and from both the FEA and ORD the MOLLE emerged. These efforts reveal several insights about the measurement methodology used, as well as, issues and features important to soldiers. The discussion below begins with some lessons learned about the measurement methodology and is followed by discussion on which LBE features were most useful to the dismounted combatant.

Questionnaires and Focus Groups

Throughout this program short, simple, yet, comprehensive questionnaires were used in combination with relevant field and laboratory activities. Experienced soldiers worked with engineers to design a system that met their requirements. Although, the questionnaires varied in minor ways in terms of wording and scales, the results were comparable between tests. In spite of the changes, the questionnaires identified the same strong and weak points of the load-carrying system which ultimately allowed engineers to tweak the design toward needed improvements. This was possible through the combined use of fixed questions, written comments and focus group

discussions. The combined data gave the design team confidence in the results.
Furthermore, quantitative scaling of items allowed statistical analysis in support of decision making.

A key lesson learned in terms of the methodology used was that the user population, the scope of the questions, and the testing environment were more important than the scaling or wording of questionnaires. Hence, it is important to conduct tests that involve users who have experience, a questionnaire that covers all of the issues, and activities that represent the user's job tasks and environment. It is also valuable to have at least one alternate, control, or baseline system to which the user can make comparisons.

Good Features, Bad Features

In terms of the load-carrying system itself, the most interesting part of MOLLE's evolution was how certain weaknesses were identified early, were repeatedly found in subsequent tests but were never eliminated until the end. In spite of many product improvements made along the way, there was one feature the users were having fundamental problems with the quick release mechanism. Many of the performance issues and concerns were related to the frame attachment. At the start of the program no one anticipated the requirement that the load, once dropped, would have to be re-attached rapidly. There was no time requirement stated in the ORD for re-attaching the main pack. However, in the field, it became very important. The time soldiers took putting the MOLLE back on was too long, too noisy and tended to be hazardous to the soldier's fingers when he or she tried to guide the probe into the latching mechanism. Since ALICE never had a re-attachment problem, it was never specified in the original requirements. At that time the emphasis was on the quick drop and no one was ready to abandon this feature. This is best understood by the fact that the quick release mechanism was, at that time, one of the early great innovations that appeared to solve a long-existing problem. The desire for an instantaneous quick release mechanism existed years before this program began. However, until the first MOLLE prototype appeared, no one had been able to design a mechanism that was both reliable and durable. In addition, the MOLLE belt-release mechanism allowed the elimination of a second belt, which was identified by users as a key problem with the ALICE. The early excitement and optimism of the new design gave nearly everyone a positive sense of accomplishment and a belief that this feature would ultimately work, once the bugs were worked out. However, after several test-fix-test cycles, the user community decided to waive the quick-release requirement from the ORD.

References

1. Sampson, JB, Leitch, DP, Kirk, J, and Raisanen, GS, Front-end Analysis of Load Bearing Equipment for the U.S. Army and U.S. Marine Corps, TR-95/024, U.S. Army Natick Research, Development, and Engineering Center, Natick, MA, June 1995.

2. Sampson, JB, Technology Demonstration for Lightening the Soldier's Load, TR-88/027, U.S. Army Natick Research, Development, and Engineering Center, Natick, MA, February 1988

3. Department of the Army Operational Requirements Document (ORD) for the Modular Load System (MLS), Headquarters United States Army Training and Doctrine Command, Ft. Monroe, VA, 4 March 1996.

APPENDICES

Appendix A

HUMAN FACTOR EQUIPMENT QUESTIONNAIRE (Condensed)
Load System

User: ______________________ Date: ______________

Rate equipment/system on each factor listed below:
Circle each item SEPARATELY. DO NOT OMIT ANY ITEMS.
(? = N/A or Can't Say)

	Very "Bad"			Neither |			Very "Good"	
1. Fit of Load-Bearing Vest (LBV)	-3	-2	-1	0	+1	+2	+3	?
2. Fit of RUCK & FRAME?	-3	-2	-1	0	+1	+2	+3	?
3. How COMFORTABLE was system?	-3	-2	-1	0	+1	+2	+3	?
4. BALANCE when loaded?	-3	-2	-1	0	+1	+2	+3	?
5. How STABLE while moving?	-3	-2	-1	0	+1	+2	+3	?
6. How easy to ADJUST?	-3	-2	-1	0	+1	+2	+3	?
7. Ability to PUT-ON QUICKLY	-3	-2	-1	0	+1	+2	+3	?
8. Ability to TAKE-OFF QUICKLY	-3	-2	-1	0	+1	+2	+3	?
9. How EASY-TO-USE w. gloves?	-3	-2	-1	0	+1	+2	+3	?
10. Ability BEND BODY wearing	-3	-2	-1	0	+1	+2	+3	?
11. Ability to BEND/MOVE ARMS	-3	-2	-1	0	+1	+2	+3	?
12. Ability to REACH pockets	-3	-2	-1	0	+1	+2	+3	?
13. Ability to WALK wearing	-3	-2	-1	0	+1	+2	+3	?
14. Ability to RUN wearing	-3	-2	-1	0	+1	+2	+3	?
15. Feel on SHOULDERS	-3	-2	-1	0	+1	+2	+3	?
16. Feel on BACK	-3	-2	-1	0	+1	+2	+3	?
17. Feel on HIPS	-3	-2	-1	0	+1	+2	+3	?
18. QUIETNESS of Load System	-3	-2	-1	0	+1	+2	+3	?
19. Design of CLOSURES/SNAPS	-3	-2	-1	0	+1	+2	+3	?
20. Design of POCKETS/POUCHES	-3	-2	-1	0	+1	+2	+3	?
21. Design of FRAME-LOCK	-3	-2	-1	0	+1	+2	+3	?
22. Design of BELT System	-3	-2	-1	0	+1	+2	+3	?
23. Compatibility w. BODY ARMOR	-3	-2	-1	0	+1	+2	+3	?
24. Ability to SHOULDER WEAPON	-3	-2	-1	0	+1	+2	+3	?
25. Ability FIRE WEAPON PRONE	-3	-2	-1	0	+1	+2	+3	?
26. Ability to LOW CRAWL wearing	-3	-2	-1	0	+1	+2	+3	?
27. Ability to CRAWL UNDER things	-3	-2	-1	0	+1	+2	+3	?
28. Ability to CLIMB OVER things	-3	-2	-1	0	+1	+2	+3	?
29. WEIGHT of System Empty	-3	-2	-1	0	+1	+2	+3	?
30. Ability RECONFIGURE missions	-3	-2	-1	0	+1	+2	+3	?
31. DURABLE/STRENGTH of system	-3	-2	-1	0	+1	+2	+3	?
32. Ability to HOLD MISSION ITEMS	-3	-2	-1	0	+1	+2	+3	?
33. STABILITY of Pouches	-3	-2	-1	0	+1	+2	+3	?
34. Ease of OPENING UP to vent	-3	-2	-1	0	+1	+2	+3	?
35. Design for GROUND ops	-3	-2	-1	0	+1	+2	+3	?
36. Design for AIRBORNE ops	-3	-2	-1	0	+1	+2	+3	?
37. Design for COLD weather	-3	-2	-1	0	+1	+2	+3	?
38. Design for HOT weather	-3	-2	-1	0	+1	+2	+3	?
39. Design for JUNGLES	-3	-2	-1	0	+1	+2	+3	?
40. Design for DESERTS	-3	-2	-1	0	+1	+2	+3	?
41. Design for CLEANING	-3	-2	-1	0	+1	+2	+3	?
42. Design for REPAIR	-3	-2	-1	0	+1	+2	+3	?
43. Design for STORING	-3	-2	-1	0	+1	+2	+3	?
44. Compared to OTHER LBE Systems	-3	-2	-1	0	+1	+2	+3	?

45. Comments:

Appendix B

Description of MOLLE 1997

The Modular Lightweight Load Equipment (MOLLE) has been engineered to increase the mobility of the fighting force by providing ergonomic features to reduce physiological energy costs of carrying heavy and bulky loads when compared to the current load bearing equipment. It is also designed to improve overall system compatibility with a wide variety of load configurations while minimizing heat stress when compared to the internal frame pack. MOLLE is designed for rapid reconfiguration to accommodate different types of loads, from approach march loads to light fighting loads by the simple removal or addition of the systems modular components. These components can be added or removed by snapping, strapping, hooking, and other fastening techniques. The use of modular pockets, pouches, or packs allow tailoring of the load to meet individual Soldier/Marine and unit mission requirements based on the commander's assessment of Mission, Enemy, Terrain, and Troops - Time (METT-T).

MOLLE is comprised of the following components:

- A fighting load carrier (FLC). The FLC is a vest that provides for the mounting of detachable pockets/pouches on the front torso area, is oriented for rapid access, and capable of holding various degrees of mission essential equipment.

- A patrol pack (fighting load carrier). The patrol pack is quickly and easily attachable/detachable to the FLC or main compartment. Shoulder straps are padded/reinforced so that the Soldier/Marine is capable of supporting/carrying at least a 40-pound load including, but not limited to, the SINCGARS radio, an extra battery, ammunition, and/or irregular shaped loads.

- A rucksack (large pack for approach march load). The rucksack is the primary carrier for the basic individual sustainment items, with a basic capacity of approximately 3,000 cubic inches, and capable of supporting/carrying a 120-pound load, to include the Javelin command launch unit. It also has an internal radio pouch, an accessible lower compartment for lightweight readily available mission items, pockets on the exterior sides, and attachment points/straps for other equipment items/carriers.

- A butt pack. The butt pack and other modular pockets/pouches are listed as system components and already exist in the system. It is intended that the capability to use/mount these items will be continued in this system with an improved mounting interface.

- A series of modular pouches/pockets are mounted on the rucksack or patrol pack to carry ammunition magazines, hand grenades, 40mm grenades, first aid equipment, canteens, NBC mask, and other items of mission essential equipment.